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The Forming Factors of High Values of Superconducting Transition Temperature T_c in 3*d*-Transition Metal Compounds

I. The Main Groups of Known Superconductors

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Abstract

The review of modern known groups of superconductors is presented. The main classification rule is the type of chemical bonding. The factors of forming superconducting transition temperature are impurities and the external pressure.

Keywords: High-temperature Superconductors, Metals, Ceramics

Experimentally found [1] that the resistance of materials to electric current at a certain temperature jump decreases to zero and materials become superconductors. In a weak magnetic field, the superconductor is diamagnetic.

Transition temperature to the superconducting state is called the critical temperature T_c. The temperature range at which this phase transition occurs, is very narrow, but can vary depending on the conditions of synthesis and the composition of the sample [2].

The first group of materials that exhibit the property of superconductivity is metals. In pure metals and alloys, superconductivity and atomic magnetism exclude each other, such as in the transition metals Co, Ni, Fe, Gd with incomplete *d*-and *f*-shells [1].

It was found that the mono valence metals (except Li [3] and Cs [1] under pressure), ferromagnetic metals (with the exception of La, which has unoccupied 4*f* shell) are not superconductors.

Impurities of elements affect the superconducting state of samples. For example, a small admixture of iron (Fe) destroys the superconductivity of molybdenum (Mo); non-metallic impurities do not have such an effect on the transition temperature, although they can change the behavior of superconductors in strong magnetic fields [1].

From the data of [4] we can conclude that most of the pure metals exhibit superconducting properties only at low temperatures. The following factors lead to the expansion of superconductors in pure metals: 1) getting very pure substances, free of impurities, and 2) increase of pressure in the experiment, and 3) providing a material in the form of thin films also contributes to the appearance of superconductivity in Li, Cs, Cr, Si , Ge, Pr, Nd, Eu, Yb.

The second group of superconductors constitutes alloys. Analysis of the symmetry of inter metallic compounds exhibiting noticeable transition temperatures to the superconducting state carried out in [4], showed that the superconductivity observed in materials with many structure of symmetries, not just cubic.

Currently, the size factor was considered as a factor which promotes the appearance of superconductivity. For example, in [5] proposed the possible existence of high values of T_c in small metal clusters.

The third group of superconductors include chemical compounds in which along with the metal atoms, and the atoms of non-metals are present, and the type of the metal-metal bonding is changed to the type of the metal-nonmetallic bonding [4].

Ceramic superconductors based on complex copper oxides are chemical compounds with a fairly narrow zone of homogeneity of the elemental composition of the samples. In the study of the family of such ceramic a great attention was paid on the ceramic materials with perovskite structure [6].

According to [6], the first superconducting perovskite structure was $BaPb_{0,8}Bi_{0,2}O_3$ with T_c = 11 K. The chain perovskites which were opened in the 70's and 80's of the last century, before the opening of a superconducting ceramic $La_{2-x}Sr_xCuO_4$, has the form: $A_nB_nO_{3n+1}$ (A = Ca, Sr, *Ln*; B = Ti, Nb); $A'A_{n-1}B_nO_{3n+1}$ (A, A '= K, Rb, Cs, *Ln*), $La_{2-x}Sr_xCaCu_2O_6$, $La_{2-x}A_xCuO_4$ (A = Ca, Sr).

The data on the conductivity of most simple and perovskite-type oxide compounds are summarized in several reviews [7, 8]. A number of perovskites that exhibit high-temperature superconductivity, includes $YBa_2Cu_3O_7$ (1-2-3) [9], bismuth (Bi) [10], thallium (Tl) [11], plumbum (Pb) [12] ceramics. The highest temperature of the superconducting transition T_c = 156 K exhibits superconducting cuprate based on mercury (Hg) [12, 13].

In [14] the features of the crystal structure of high-temperature superconductors $YBa_2Cu_3O_7$ (T_c = 93 K) were investigated. It is shown that the structure of the copper-oxygen complexes is not changed in the transition at temperatures below T_c.

Along with ceramics based on copper oxide, were considered [15] a series of ceramics with chemical substitution of copper atoms to atoms of other metals. Studies have shown that such a metals as nickel (Ni) and zinc (Zn), even at low concentrations, lead to a sharp reduction in T_c, other - iron (Fe) and aluminum (Al) less effect on the superconducting transition temperature, but also reduce its . When you replace part of the copper atoms (Cu) on the atoms of cobalt (Co) T_c even increases from 92 K in the undoped sample to 94.3 K for x = 0,05 in $YBa_2Cu_{3-x}Co_xO_{7-y}$ [15]. A full review of the possible substitutions in the structure of superconducting based on copper ceramics for the period up to 1993 is presented in [8].

In the early 2000s, have been synthesized copper-free representatives of the third group of superconductors - MgB_2 ceramics [16]. Currently, the greatest interest in the new complex superconducting copper-free ceramics are complex oxopniktidies and chalcogenides of ferrites lanthanides [17, 18]. In terms of the feasibility of the superconducting state the fourth group of promising superconductors constructs the systems which involve hydrogen (H) [19].

In subsequent studies, we will present the results of quantum-chemical calculations of the electronic structure, the parameters of the electron-nuclear hyperfine interactions, chemical bonding and the superconducting transition temperature T_c, which were performed for the coordination polyhedra 3*d*-metals within the real structure of various types of high-temperature superconductors.

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